

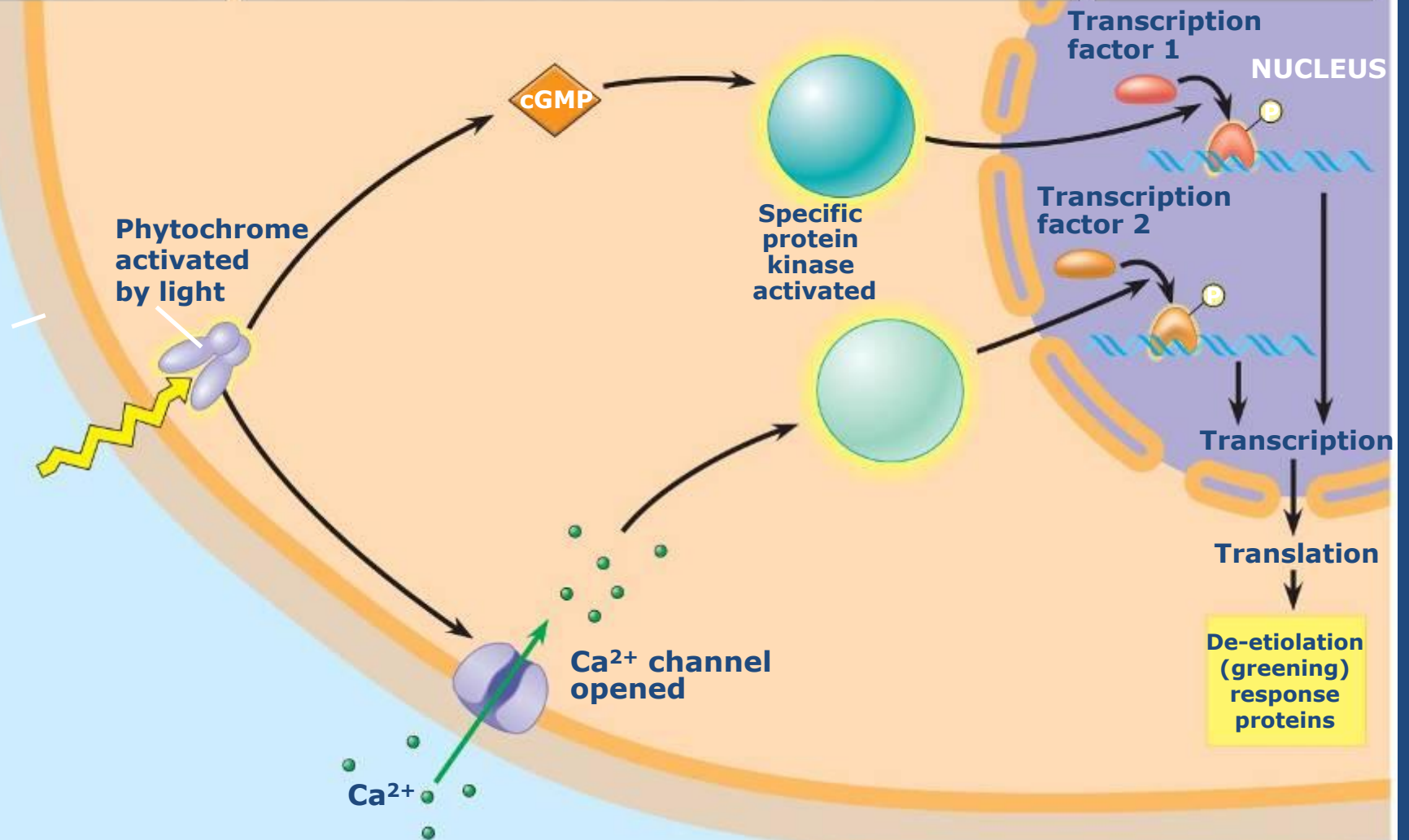
Plant Hormones and Signal Transduction



1 Reception

2 Transduction

3 Response



Overview

- ◆ Known as plant hormones, plant growth regulators (PGRs), phytohormones
- ◆ Mediate growth and development
- ◆ Mobile throughout plant
- ◆ Can be used in response to environment

Plant growth regulators

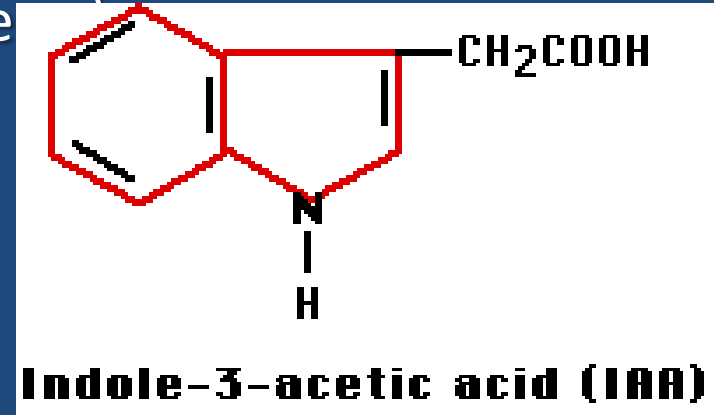
- Organic compounds produced in low concentrations
- Transported to another part of plant (i.e. target)
= **ectohormones**
- Cause physiological or developmental responses (stimulatory or inhibitory)
- Produced in one part of plant (i.e. source)

General plant hormones

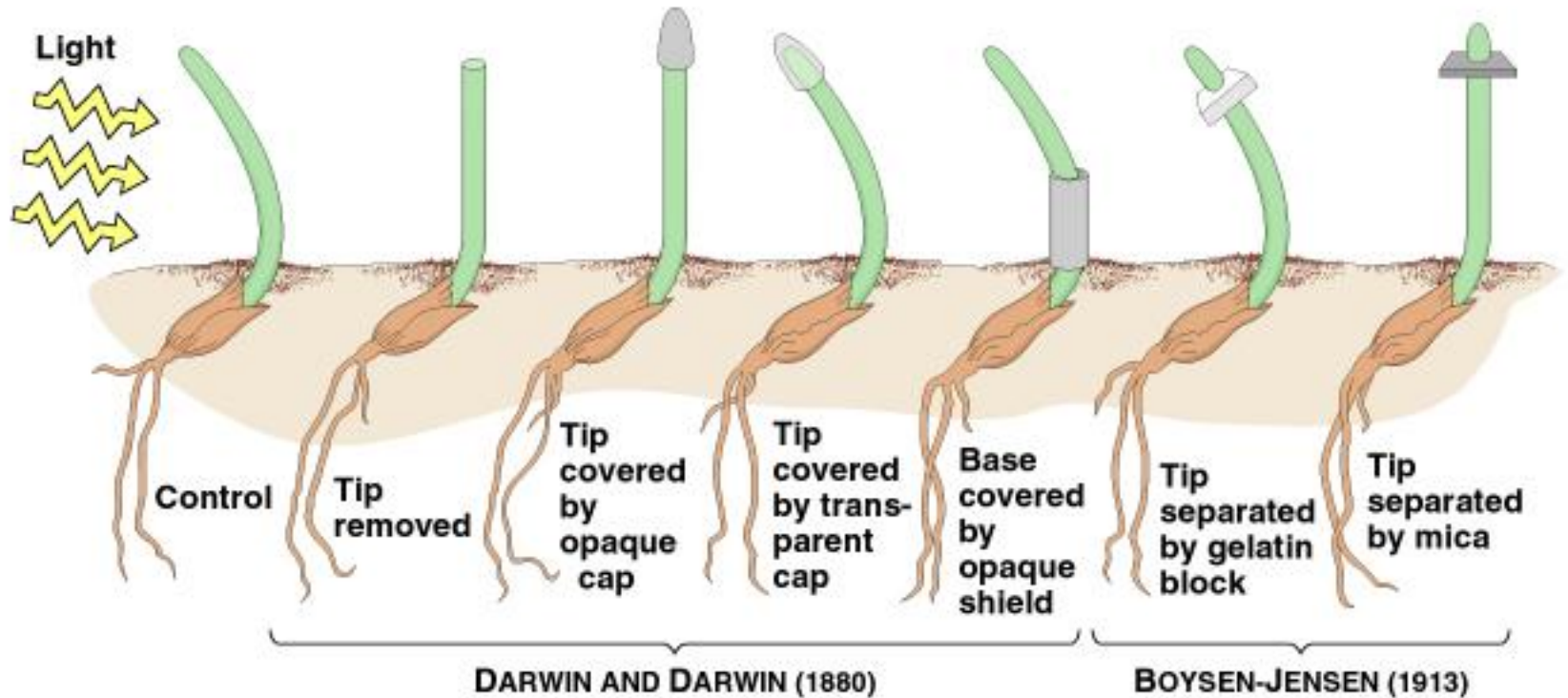
- Auxins
- Gibberellins
- Cytokinins
- Abscissic acid
- Ethylene

Plant Hormones

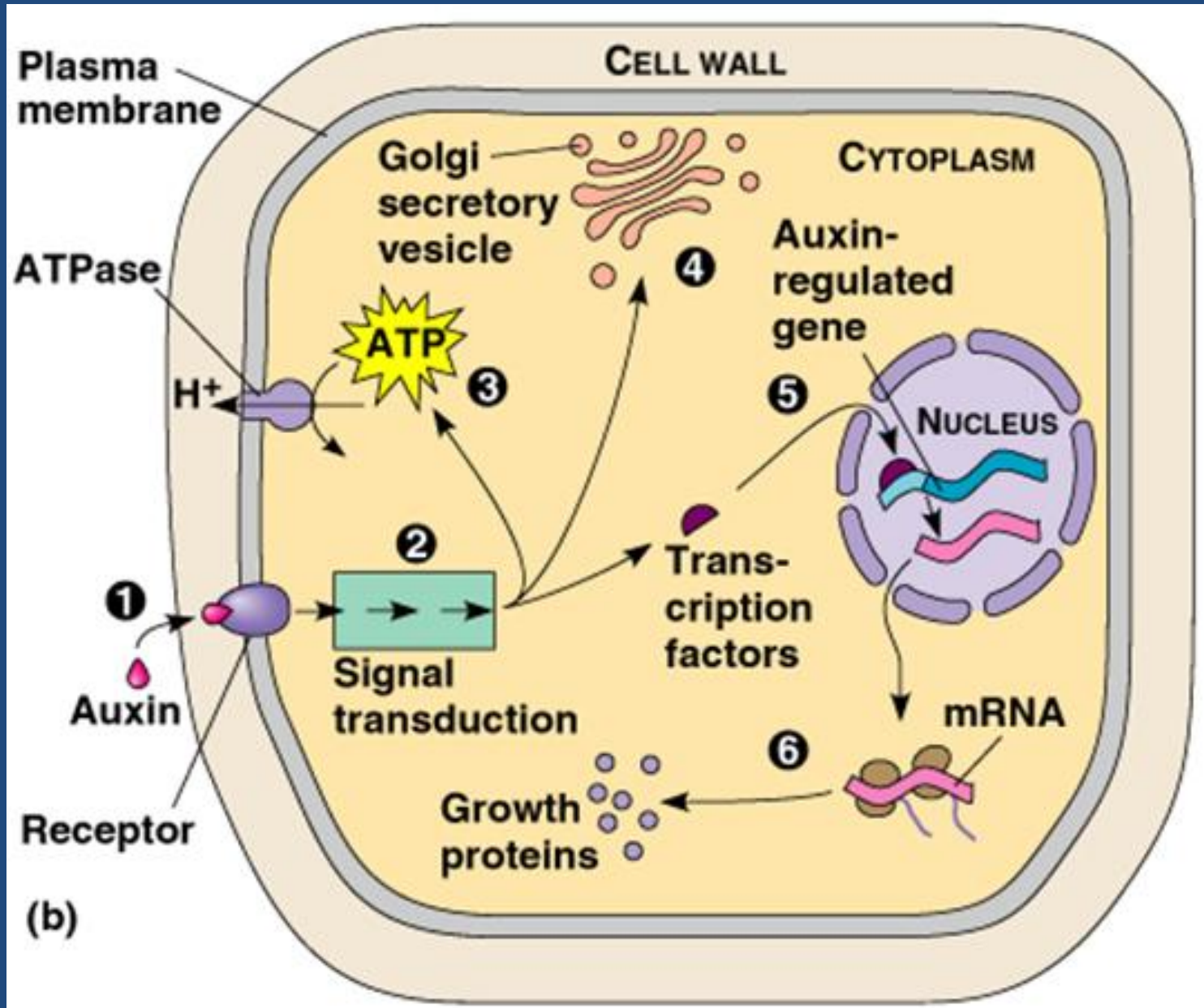
- Auxins
 - Types of auxins used in horticulture
 - Natural auxin is indole-3-acetic acid (IAA)
 - IAA is broken down in sunlight
 - Synthetic auxins used in horticulture:
 - Indole-3-butyric acid (IBA)
 - Naphthaleneacetic acid (NAA)
 - 2, 4-dichlorophenoxyacetic acid (2, 4-D)
 - Site of auxin production in plants:
 - Shoot and root tips (apical meristems)
 - Young, expanding leaves
 - Young seeds



Auxin associated with phototropism - tip as receptor.



Signal-transduction pathways by auxin

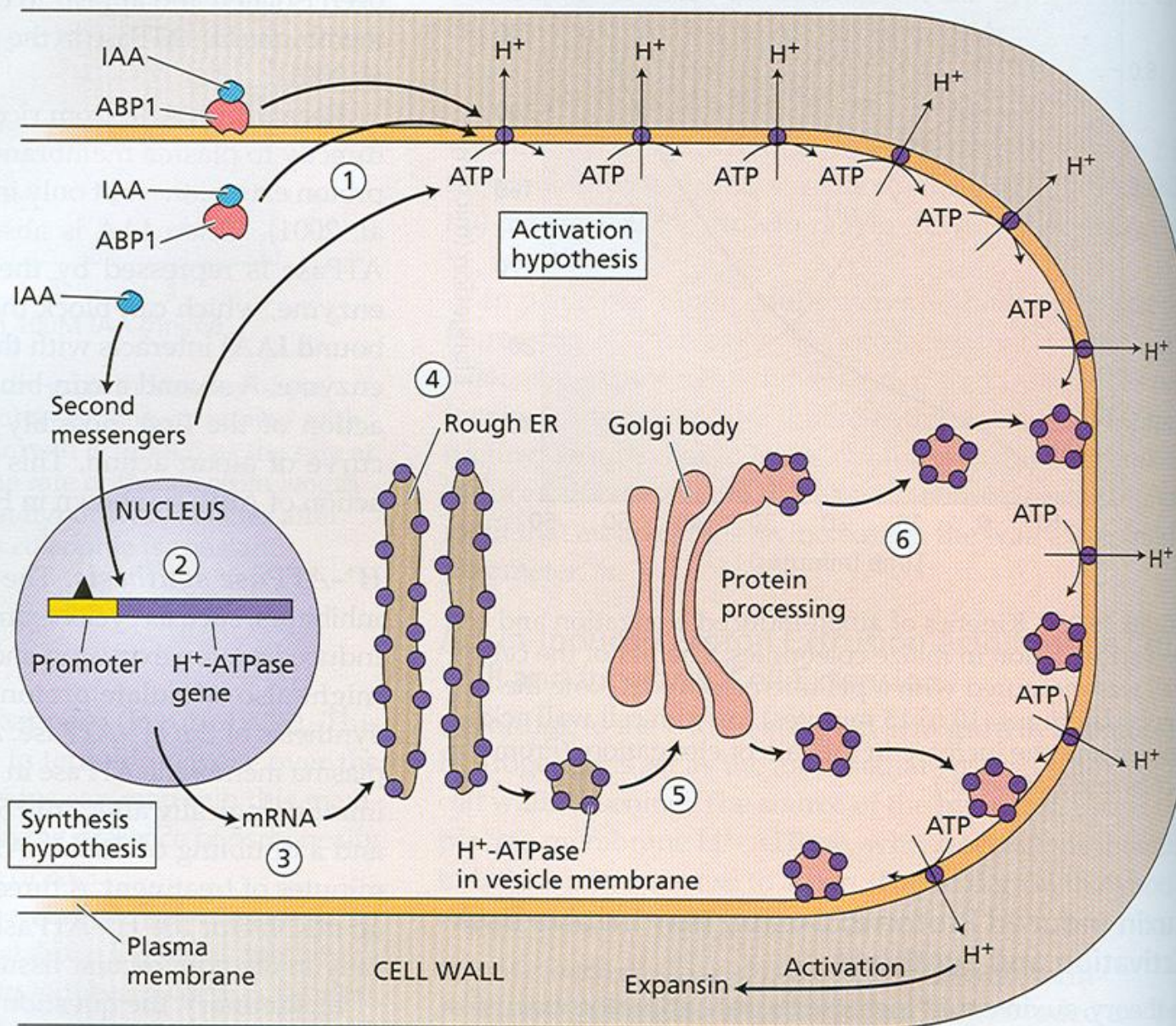


Activation hypothesis:

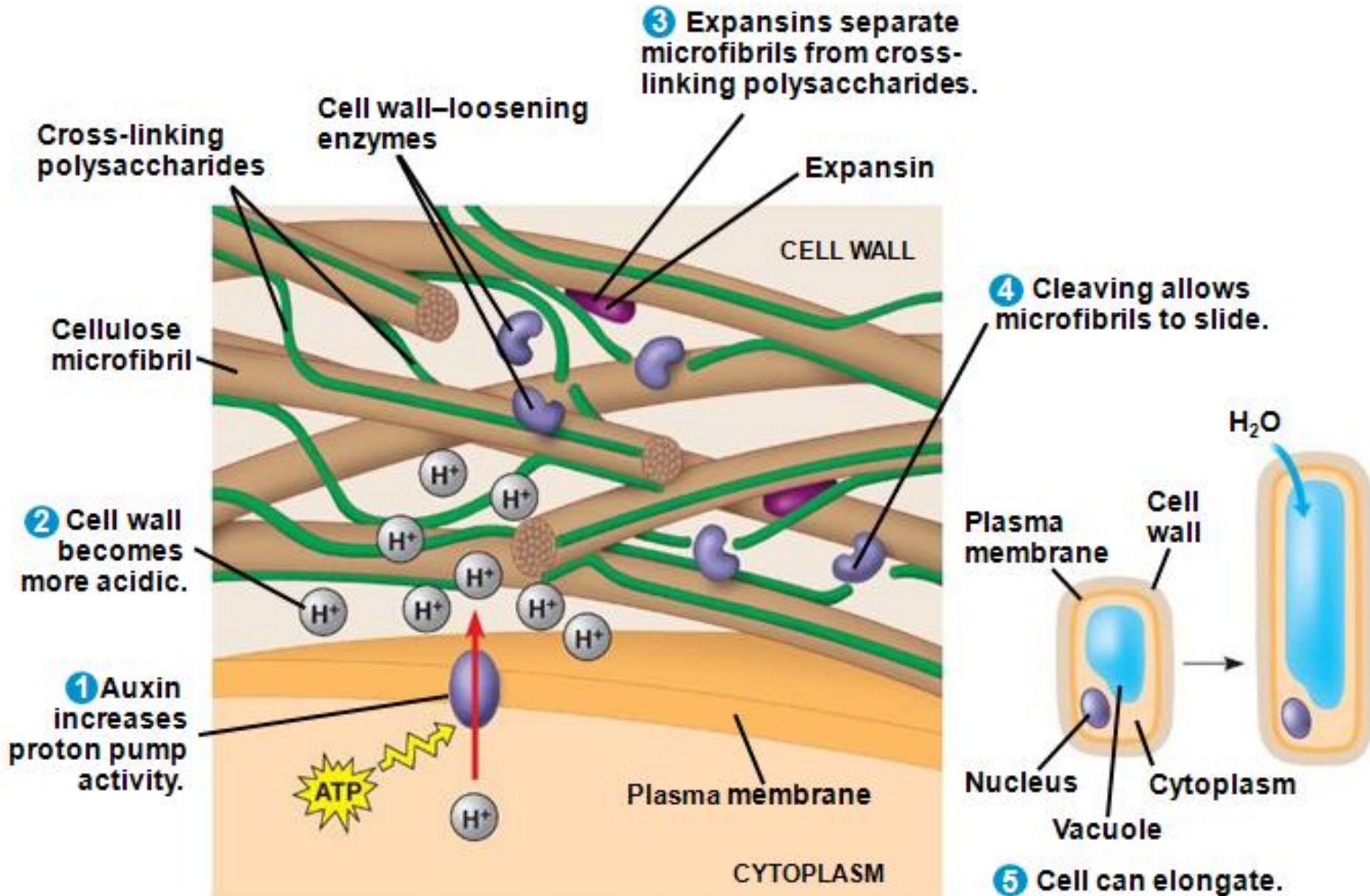
Auxin binds to an auxin-binding protein (ABP1) located either on the cell surface or in the cytosol. ABP1-IAA then interacts directly with plasma membrane H^+ -ATPase to stimulate proton pumping (step 1). Second messengers, such as calcium or intracellular pH, could also be involved.

Synthesis hypothesis:

IAA-induced second messengers activate the expression of genes (step 2) that encode the plasma membrane H^+ -ATPase (step 3). The protein is synthesized on the rough endoplasmic reticulum (step 4) and targeted via the secretory pathway to the plasma membrane (steps 5 and 6). The increase in proton extrusion results from an increase in the number of proton pumps on the membrane.



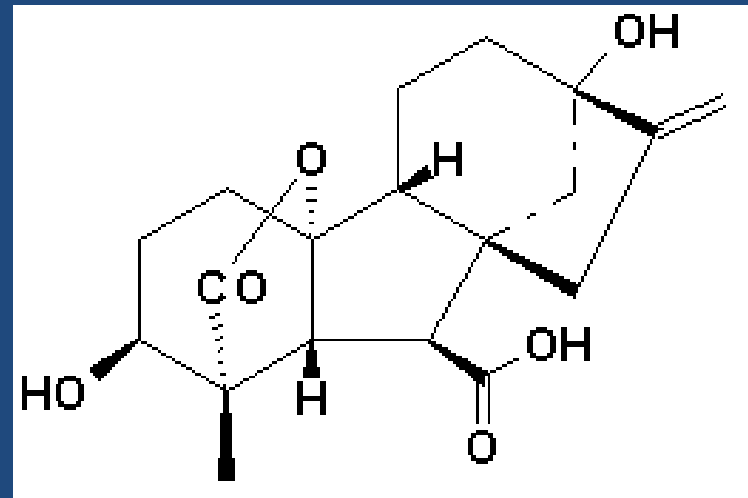
Loosening of cell wall



Plant Hormones

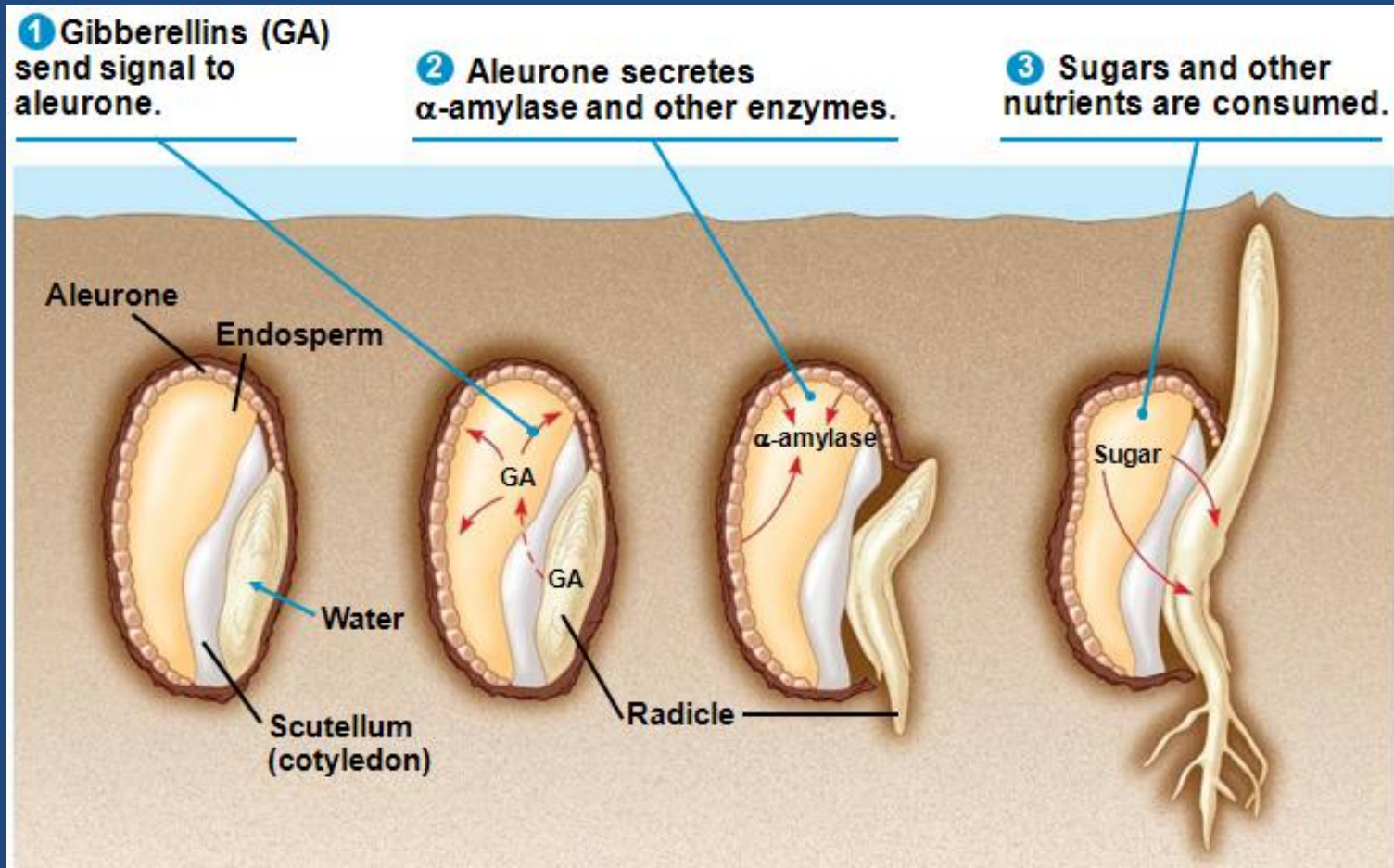
- **Gibberellins**

- Types of gibberellins used in horticulture
 - Several different gibberellins (GA) produced by plants
 - Large, complicated molecules not synthesized
 - Commercial gibberellins produced by fungus
- Site of gibberellin production in plants:
 - Shoot and root tips (apical meristems)
 - Young, expanding leaves
 - Embryos
 - Fruits
 - Tubers

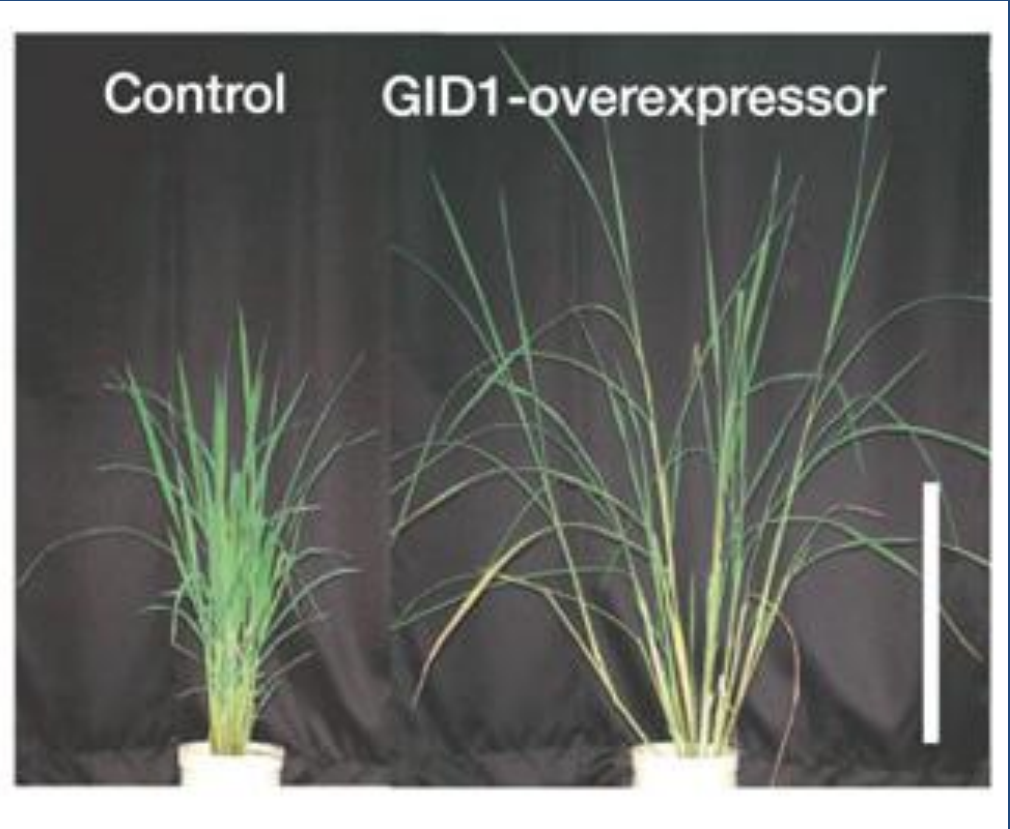


Effects of Gibberellins

- General cell elongation.
- Breaking of dormancy.
- Promotion of flowering.
- Transport is non-polar, bidirectional producing general responses.

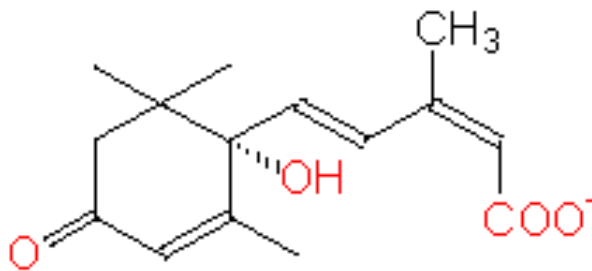


Modification of GA in Rice

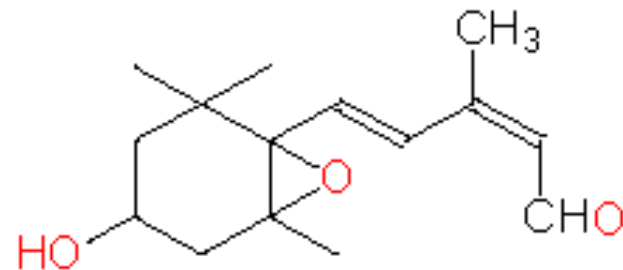


Plant Hormones

- Absciscic Acid (ABA)
 - Similar structure as gibberellins
 - Site of absciscic acid production in plants:
 - All organs (e.g. roots, leaves, stems, fruits)
 - Actions of absciscic acid in plants
 - Counteracts effects of auxins and gibberellins
 - Maintains dormancy in seeds and buds
 - Stimulates guard cells to close stomates (to conserve water)



abscisic acid (ABA)

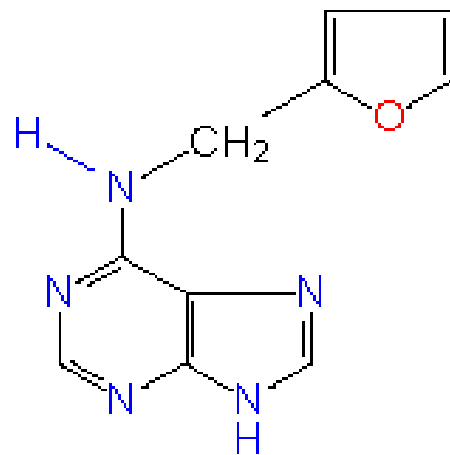


xanthoxine

Plant Hormones

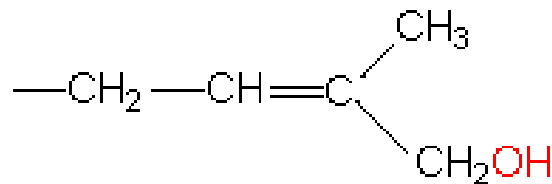
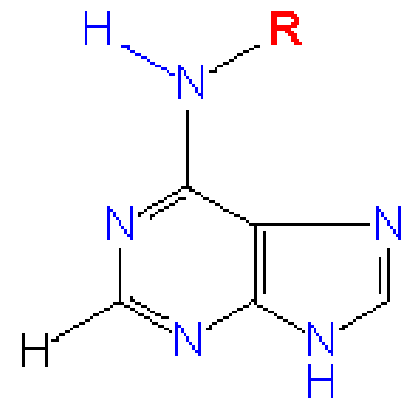
- Cytokinins
 - Types of cytokinins used in horticulture
 - Several natural forms
 - Zeatin first cytokinin isolated
 - Synthetic cytokinins used in horticulture:
 - Benzyladenine (BA)
 - Site of cytokinin production in plants:
 - Embryos
 - Young leaves and fruit
 - Apical meristems of roots

Cytokinins



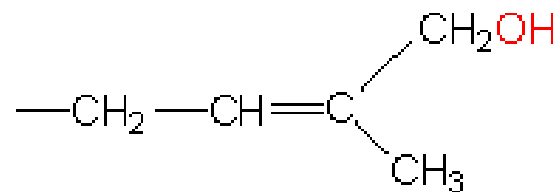
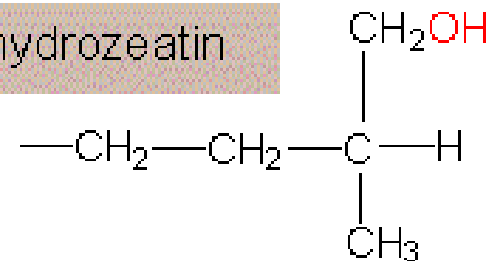
kinetin:
6 - (2 - furfuryl -
7 - amino purine)

cytokinin
(basic structure)



zeatin

dihydrozeatin



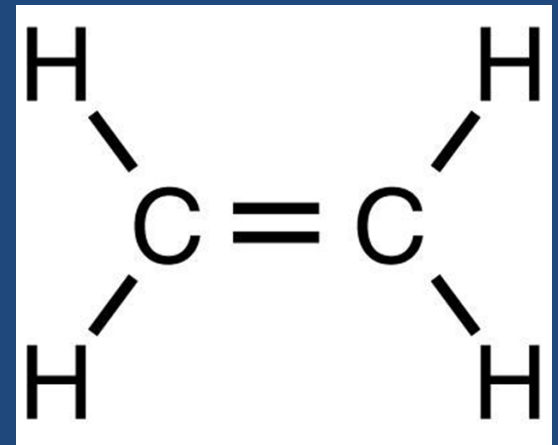
Function of cytokinins

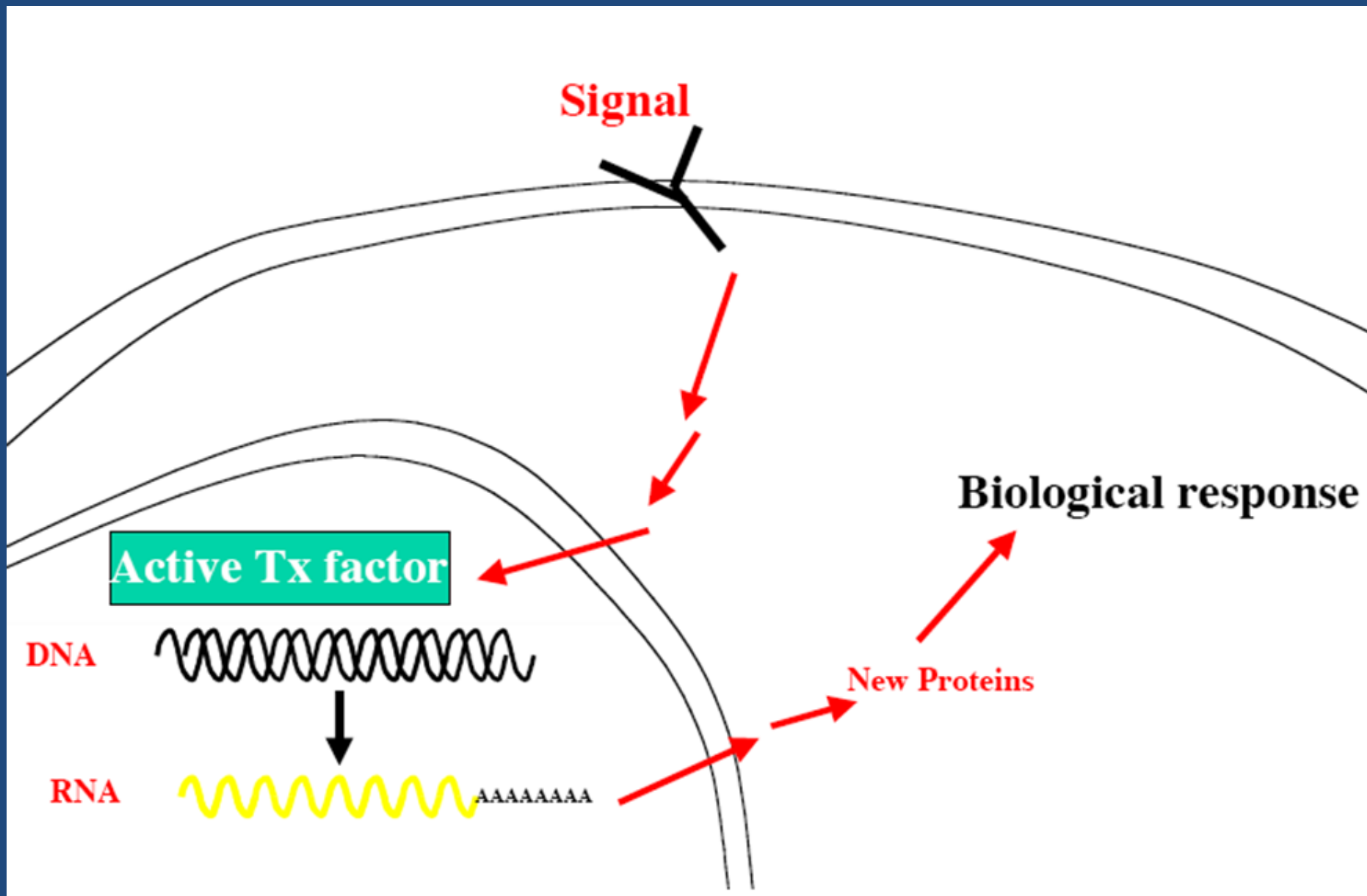
- Promotes cell division.
- Morphogenesis.
- Lateral growth of shoots
- Delay of senescence.
- Rapid transport in xylem stream
- ◆ Cytokinesis (cell division)
- ◆ Accidentally added degraded DNA to medium
- ◆ Organization and development of xylem tissue
- ◆ Response to light
- ◆ Open stomata

Plant Hormones

- Ethylene

- Gas at physiological temperatures
 - Liquid form used in horticulture (ethephon)
- Site of ethylene production in plants:
 - Throughout plants
- Actions of ethylene in plants
 - Inhibits root and shoot elongation by blocking transport of auxins from apical meristems
 - Stimulates leaf curling (epinasty)

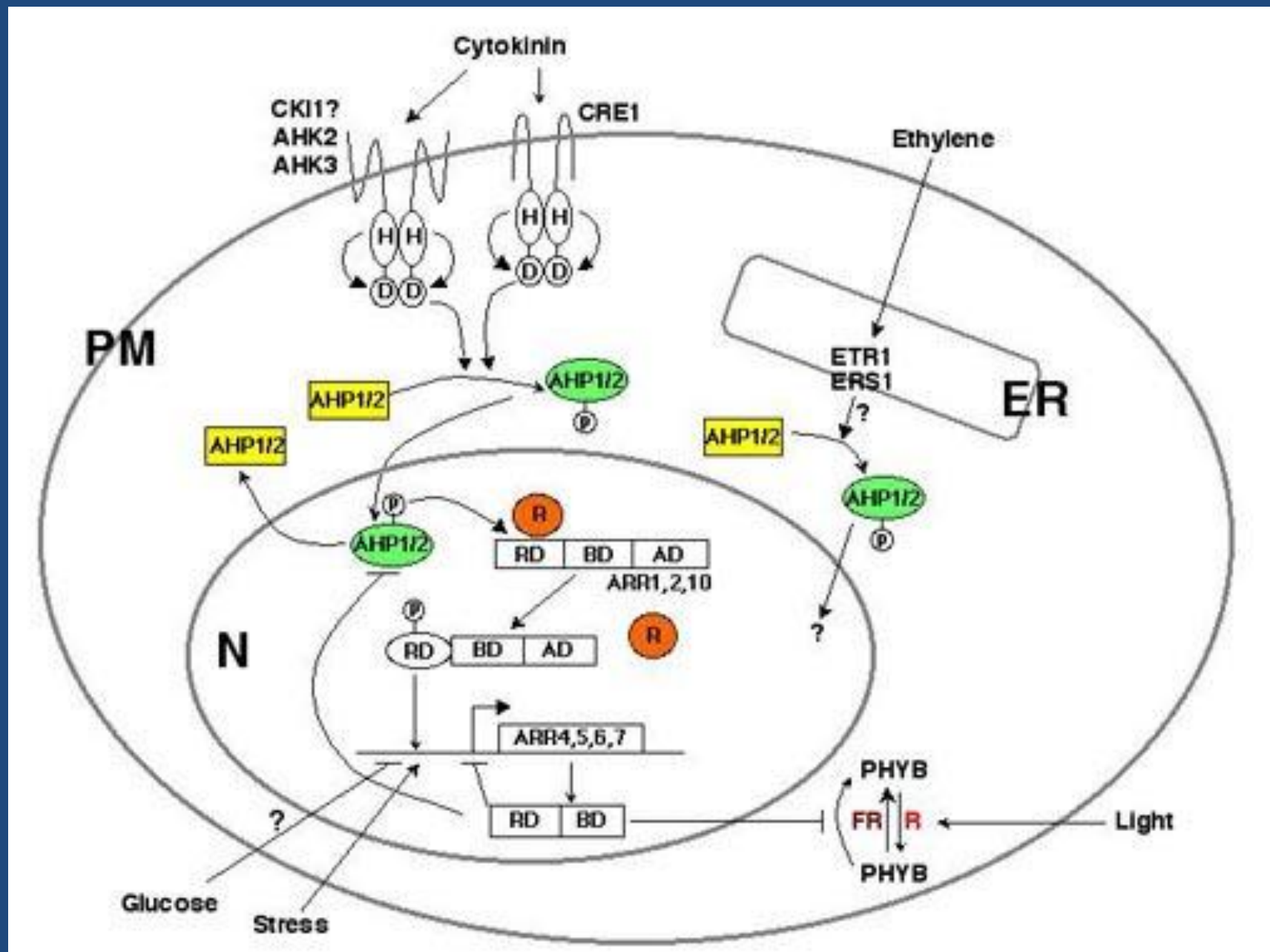




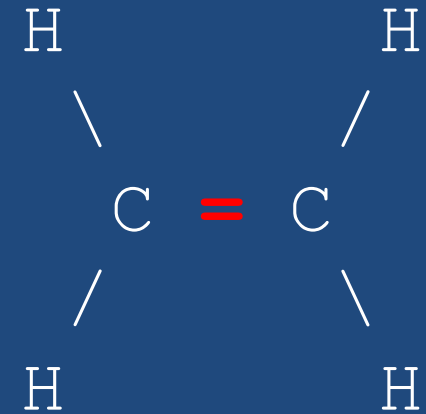
Growth and Development

- ◆ Controls stem and root growth with cytokinin
 - Higher auxin induces root growth
 - Equal ratio induces callus and cell enlargement
 - Lower auxin induces shoot growth
- ◆ Also influenced (usually inhibited) by ethylene production

Arabidopsis Histidine Kinase sensing and signaling



Specific features and functions of ethylene



- Gaseous in form
- Rapid diffusion
- Affects adjacent individuals
- Fruit ripening
- Senescence and abscission
- Interference with auxin transport
- Initiation of stem elongation and bud development

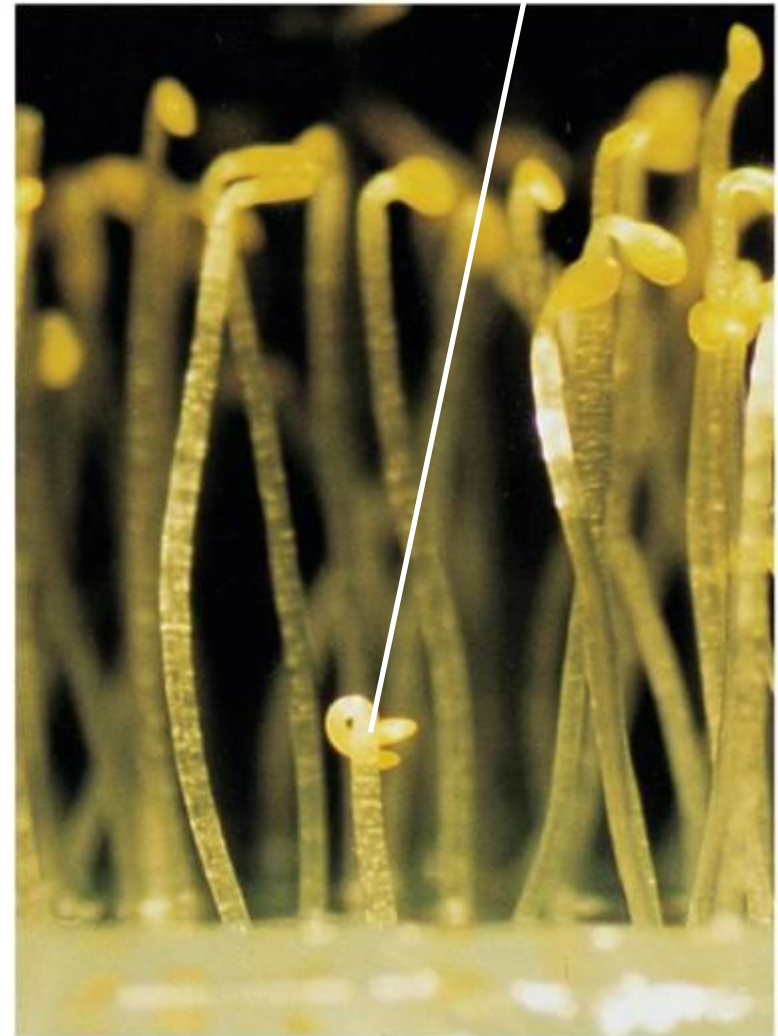
The Triple Response to Mechanical Stress

- ◆ Ethylene induces the **triple response** , which allows a growing shoot to avoid obstacles
- ◆ The triple response consists of a slowing of stem elongation, a thickening of the stem, and horizontal growth

- ◆ **Ethylene-insensitive mutants (*ein-*)** fail to undergo the triple response after exposure to ethylene
- ◆ Other mutants undergo the triple response (***ctr-***) in air but do not respond to inhibitors of ethylene synthesis



ein mutant



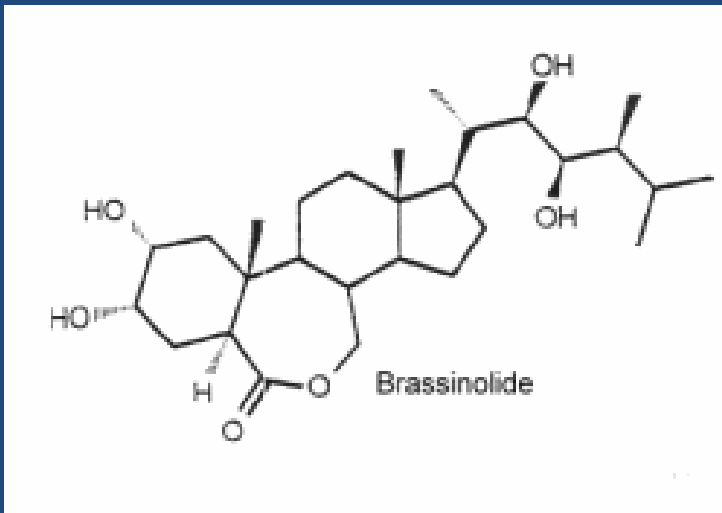
ctr mutant

New growth regulators

- ◆ Brassinosteroids
- ◆ Jasmonates
- ◆ Salicylic acid
- ◆ Polyamines
- ◆ Signal peptides
- ◆ Olygosaccharides

Brassinosteroids

- ◆ Sixty steroidal compounds.
- ◆ Effective at low concentrations.



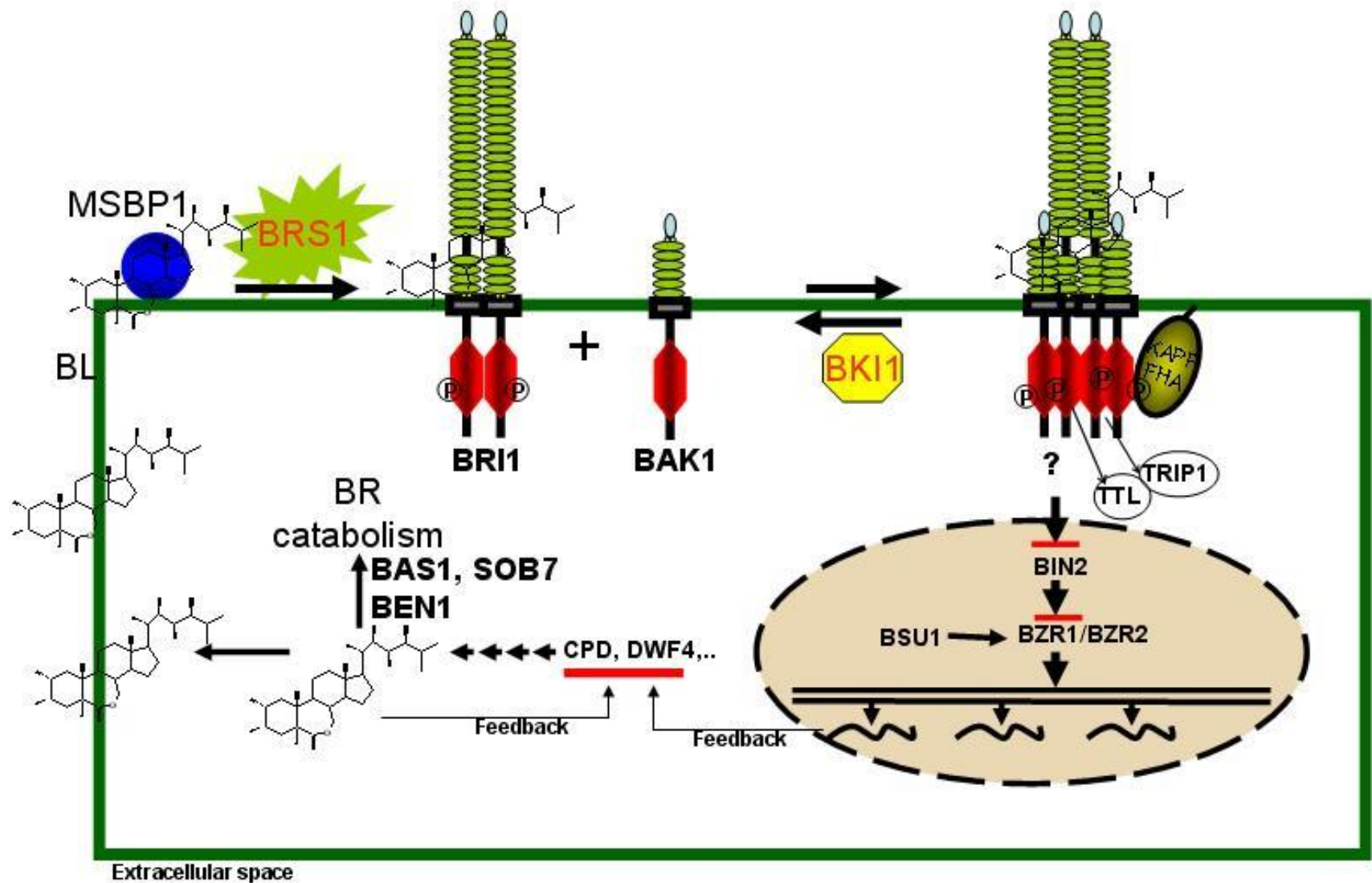
Stimulate

- ◆ Cell division
- ◆ Cell wall loosening
- ◆ Vascular differentiation
- ◆ Ethylene biosynthesis

Required for fertility

Inhibit root development and growth

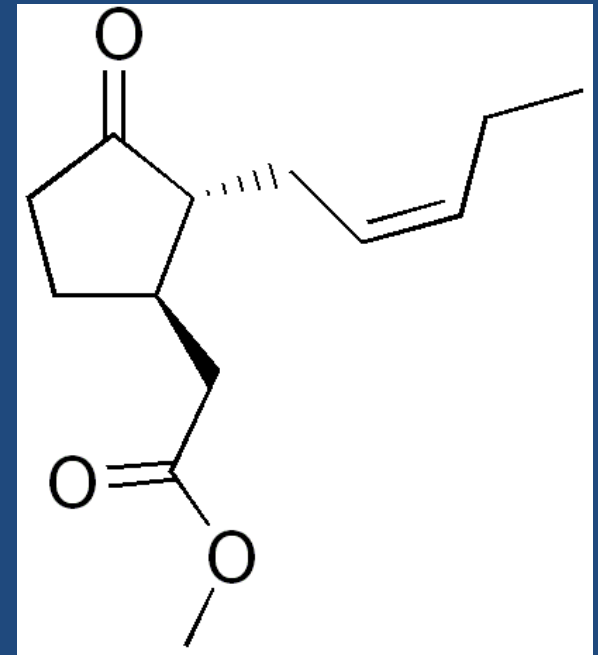
A current model of BR signaling pathway



Jasmonates

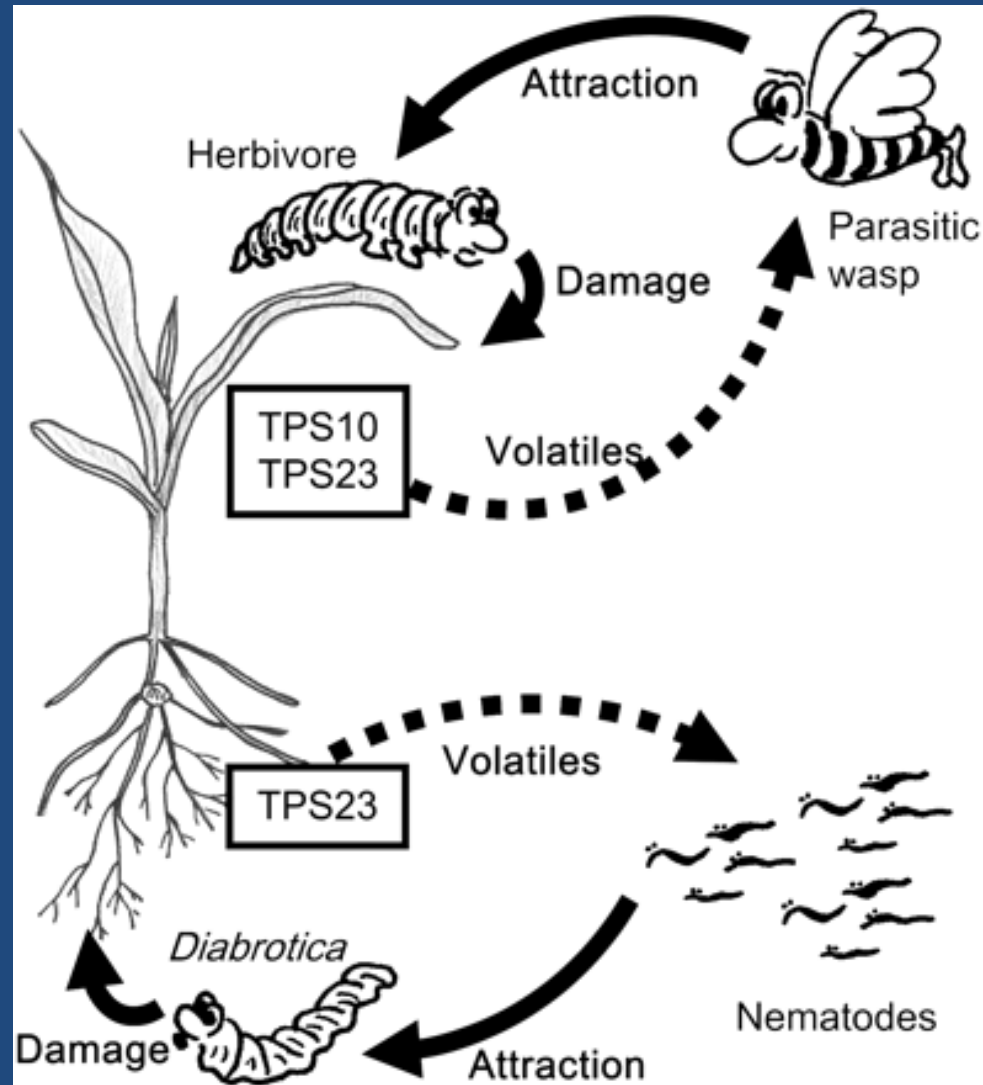
- ◆ Jasmonic acid is most common
- ◆ Methyl esters
- ◆ Scented

- ◆ Induce tuberization
- ◆ Important in plant defense
- ◆ Inhibit growth
- ◆ Inhibit germination
- ◆ Promote senescence
- ◆ Promote pigmentation
- ◆ Wounding induces JA biosynthesis
- ◆ Microbial and fungal invasion

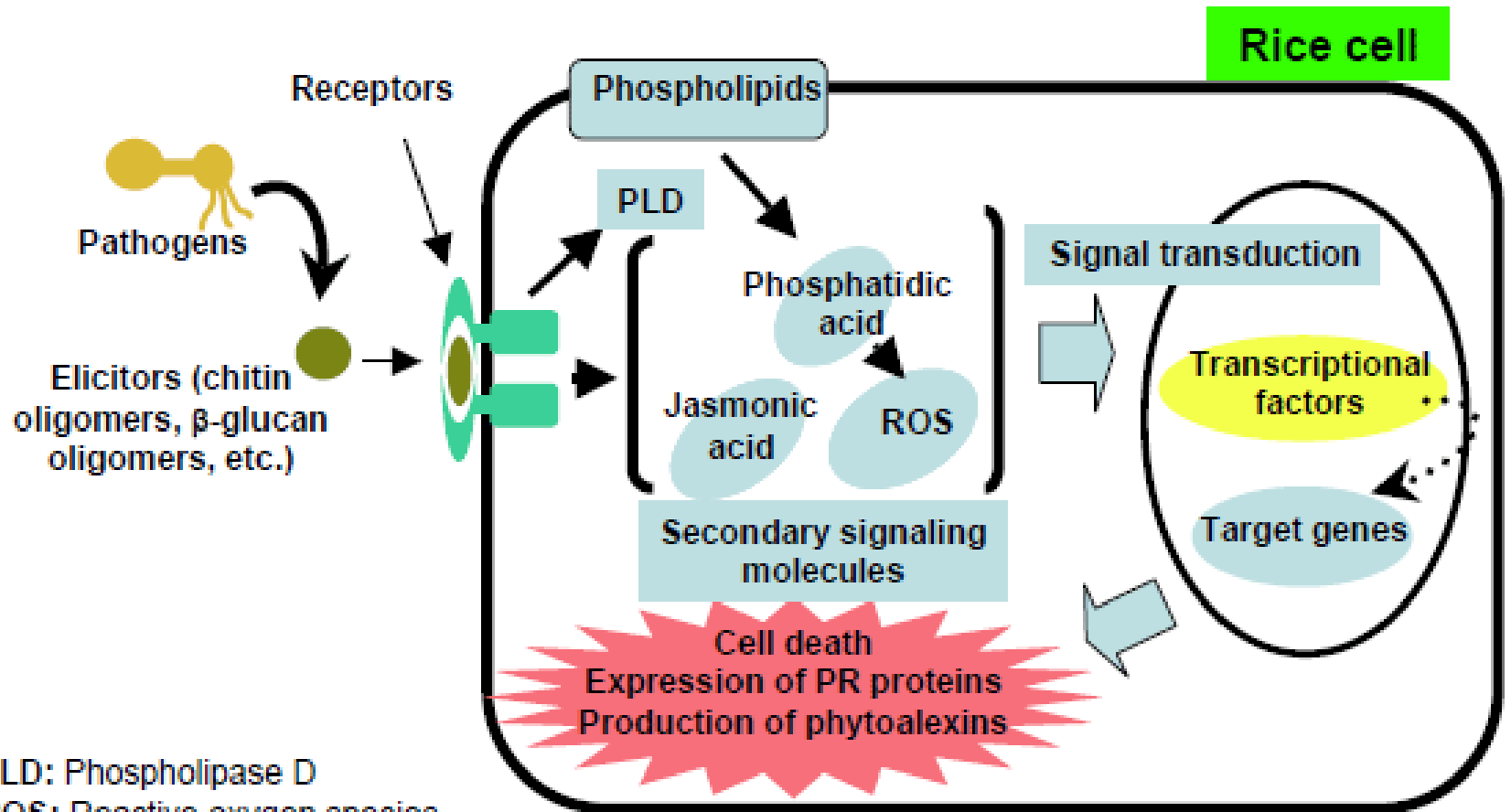


JA Application

Tri-trophic interactions



Degenhardt (2009)
Plant Physiology
149:96-102



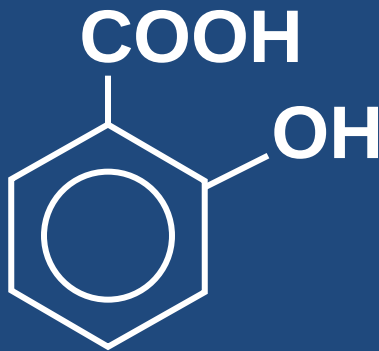
PLD: Phospholipase D

ROS: Reactive oxygen species

PR proteins: Pathogenesis-related proteins with anti-microbial activity

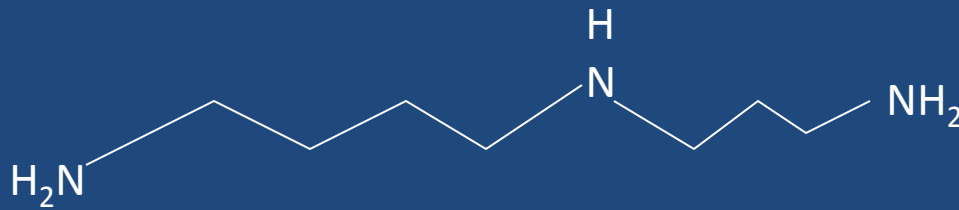
Phytoalexins: Plant antibiotics (secondary metabolites with anti-microbial activity)

Salicylic Acid



- ◆ Synthesized from phenylalanine.
- ◆ Promotes production of pathogenesis related proteins.
- ◆ Can reverse effects of ABA in some cases.

Polyamines



Spermidine structure

- ◆ Aliphatic amines.
- ◆ Putrescine, spermidine and spermine are most common.
- ◆ Effective at low concentrations.
- ◆ Mutants have aberrant development.

Signal Peptides

- ◆ Small molecules that can be transported throughout the plant and effect development.
- ◆ Involved in defense response
- ◆ Help determine cell fate
- ◆ Involved in self-incompatibility
- ◆ Involved in nodule formation in legumes

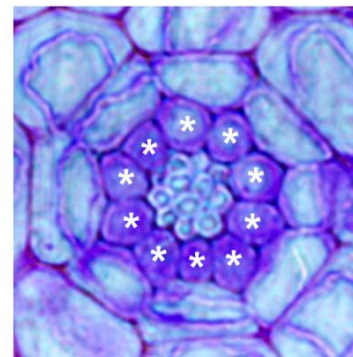
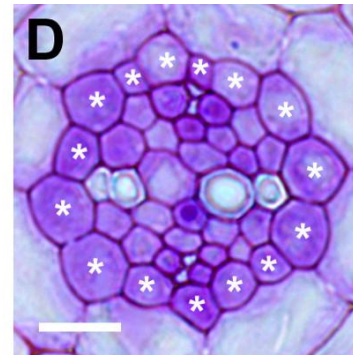
**Brassinosteroid
mutant**



**Ethylene
mutant
grown in dark**



**Cytokinin
mutant**



**Cytokinin
mutant
closer look**



**Absciscic acid
mutant**

Hormone/PGR Biosynthesis

Are made from four biosynthetic pathways:

- Terpenoids
 - ◆ AMP + IPP (cytokinins)
 - ◆ Carotenoid breakdown (abscisic acid)
 - ◆ Diterpene (gibberellic acid)
 - ◆ Triterpene (brassinosteroids)
- Fatty acids (jasmonic acid)
- Tryptophan (auxins)
- Methionine (ethylene)